Staff Paper

SEQUENTIAL EVALUATION OF AGRICULTURAL RESEARCH:
FOUNDATIONS, INDICATORS AND USE

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Executive Summary

The social impact of any agricultural research program, no matter how successful the program has been in generating scientific advances, will depend on policy and agroeconomic factors such as price policy and market efficiency. As these factors change, the type and focus of research outputs relevant to the agricultural sector also changes. The problems faced by research system directors are that it is difficult to perceive which policy and agroeconomic changes warrant a change in research emphasis, and if such a change in emphasis is appropriate, then it is difficult to guide the redirection.

These interactions create two problems for research managers: how to track changes in farm, economic, and policy factors, and how to modify the research program to respond appropriately to these changes.

The paper develops a framework for the sequential evaluation (SE) of agricultural research programs. Sequential evaluation is a dynamic technique which bridges the gap between ex-ante methodologies applicable at the start of the research program, and ex-post methodologies which assess impacts upon completion of the program. The economic foundation of SE is a dynamic optimization problem that models how research programs could evolve to take advantage of changing policy and agroeconomic situations. Sequential evaluation reduces this complex, dynamic optimization problem into an implementable evaluation technique. The basis of this simplification is a set of indicators of change in the policy and agroeconomic environment. These indicators can be used, either by themselves or in conjunction with ex-ante methods, to provide a preliminary assessment of the research program. Changes in the indicators signify changes in the state of the environment. The assessment of the research program is then updated to reflect the changing environment, and the updated assessment provides guidance for changing the research emphasis.

Sequential evaluation covers the entire life of the research program, continually updates results as research, policy and market situations evolve, and complements existing ex-post and ex-ante techniques. It can be used to modify research programs, to improve research efficiency, and to better achieve program objectives.

The two most commonly used research evaluation methodologies are ex-post and ex-ante evaluation. The fundamental economic concepts underlying these two methods are the same. However ex-post is backward looking and evaluates the impact of research after completion, while ex-ante is forward looking. These methodologies are usually not sufficient to evaluate ongoing research program implementation, technology diffusion and adoption.

Sequential evaluation can be conducted by most research systems, and it should be part of the regular activities of a socioeconomic unit within a research system.

An example shows how sequential evaluation might be applied to the Uruguayan rice resarch program. Recent changes in world market conditions suggest that the program be reassessed. Despite some adverse market developments, a partial analysis indicates that there is a continuing need for rice production research, technology borrowing, and marketing research.

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1. INTRODUCTION

1.1 Objectives

The social impact of any agricultural research program, no matter how successful the program has been in generating scientific advances, will depend on policy and agroeconomic factors such as price policy and market efficiency. Interactions between agricultural innovations and changing farm, economic, and policy factors affect the private and social benefits and costs attributable to research, technology transfer, and adoption. The size and nature of these interactions often change over time. The intertemporal effects of these interactions follow a complex pattern because of the time lag between the beginning of a research program and the farmers' adoption of the resulting innovation(s), and because benefits from adoption of these innovations may continue for several years.

These interactions create two problems for research managers: how to track changes in farm, economic, and policy factors, and how to modify the research program to respond appropriately to these changes.

Previous evaluations of agricultural research have not focused on these two problems. Agricultural research is often evaluated looking at the past, to assess the impact of research after completion (ex-post assessment), or looking forward, to guide research resource allocation by prioritizing among competing programs (ex-ante assessment). These methodologies usually do not take into consideration the dynamic of interactions between public and private research activities and of interactions between technical change agroclimatic, research, policy and market factors. They do not track changes in policy or agroeconomic conditions.

The objectives of this paper are:

1) to develop a procedure for the evaluation of ongoing agricultural research programs, and

2) to illustrate the application of this methodology with an example.

1.2 Methodologies for evaluation of agricultural research

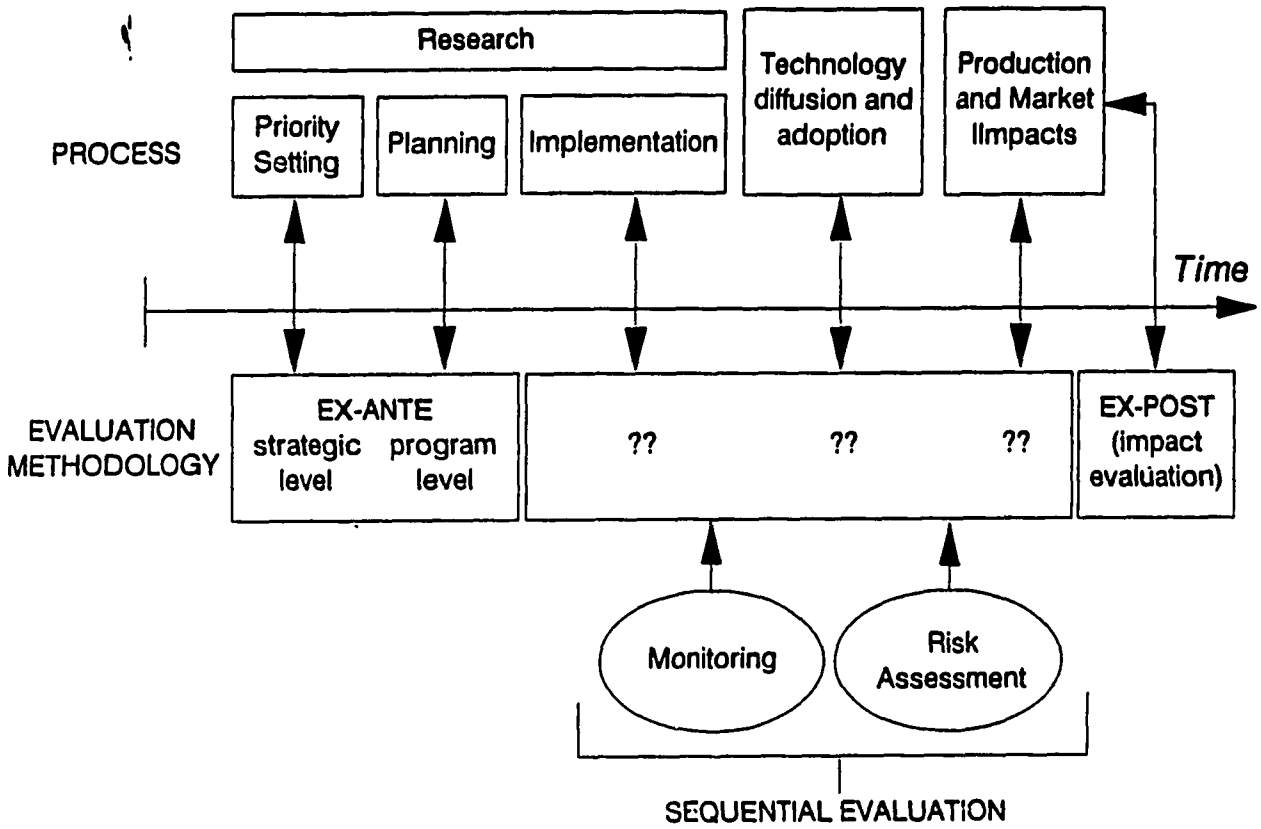
The two most commonly used research evaluation methodologies are ex-post (EP) and ex-ante (EA) evaluation. The fundamental concepts underlying these two methods are the same. In either type of evaluation a research program is said to be successful if it increases social surplus (a measure of economic efficiency related to national income), the well-being of low-income or other target groups, or if it decreases income fluctuations (Norton and Pardey 1987).

Ex-post evaluation of previous research identifies areas of past success. It shows budget planners when agricultural research has met societal goals--and therefore helps in securing continued funding. It also provides information on the factors that have made previous research successful. Ex-ante evaluation of research is based on currently available data and on estimates of future developments (adoption, prices, etc.).

The relationship of the methodologies to the process of research and technical change is depicted in figure 1. In the first stage research objectives are determined and priorities are set. EA priority setting exercises can help at this stage, and may give rise to ideas about potential programs or projects. Program planning and project conceptualization follows. EA program evaluation assesses the potential impacts of particular programs.

The implementation stage is when the actual research investigation is carried out. Many research systems have no formal priority setting or planning framework, and may move directly to implementation. During this stage monitoring tracks the progress of the research and the success of the program in delivering

Figure 1. Relationships between research, technology generation and diffusion, and research evaluation methodologies



The top row is a stylized representation of the technical change process. The bottom row shows the stages at which current evaluation methodologies are appropriate. The solid vertical lines represent the connection between current evaluation methodologies and the technical change process. The question marks indicate the lack of evaluation tools at this stage. Monitoring and risk assessment provide relevant information but do not place economic values on research outputs. Sequential evaluation satisfies this need.

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outputs on schedule. Although monitoring is often linked with the word "evaluation," it usually does not assess consequences of the research, or even of the consequences of tardy delivery. This current lack of evaluation capability is captured by the question marks under the time line.

In the next stage research results are disseminated through extension services, distribution networks, and other systems. Farmer adoption of the innovation occurs at this stage. Attempts have been made to link adoption rates and ceilings to characteristics of the innovation, such as profitability (Griliches 1957) and risk (Jansen and Lynam 1990). As yet, these links are incomplete, and evaluation procedures are lacking.

Finally, the effects of research are reflected by technical change in the production process, and by changes in the marketplace. After these changes are quantified, an EP investigation could be used to evaluate the success of the project.

Figure 1 highlights the need for research evaluation during the middle stages. Because EP evaluation is backward looking, it is best used after the final stage of the technical change process. EA priority setting and program evaluations can rely on the same economic fundamentals as EP evaluation, and are forward looking. Unfortunately, they are costly and time-consuming to undertake, and so not suited for replication throughout the life of a research program. For example, ex-ante scoring models "are better suited for periodic or major priority-setting efforts than for situations where frequent marginal changes are anticipated" (Norton and Pardey 1987:4). As we will discuss in more detail below, monitoring and evaluation and risk assessment and not comprehensive evaluation procedures. The need for evaluation in the middle stages is noted by Horton (1990) and by Swanson et al. (1990). As seen in the lower portion of figure 1, a sequential evaluation fills this gap by incorporating the middle stages into the assessment.

1.3 What is sequential evaluation?

Sequential evaluation (SE) is a procedure for the assessment of ongoing agricultural research programs. The defining characteristic of the SE procedure is that it develops a set of indicators which measure change in the research and agroeconomic environments, and assess the impact of these changes on the social benefits and costs of research. Finally, it suggests possible research program responses to the changing research and agroeconomic environment.

Sequential evaluation has three distinguishing features. First, it is a dynamic approach which bridges the gap between ex-ante and ex-post methodologies. Second, SE is based on the heuristic application of economic principles. This distinguishes SE from traditional monitoring and evaluation methodologies which focus attention on the inputs of research, and the delivery of research outputs, but not on the valuation of these outputs. Third, SE focuses on four major considerations which affect the social benefits and costs of public research: research opportunities, transfer and adoption of techniques, interactions with other sources of technology, and policy interventions. Explicit attention to these considerations is lacking in many applications.

The use of SE improves program management and implementation by updating evaluations of research in progress.[1] It is not a replacement for EA or EP evaluation since both approaches provide valuable information, and EA assessments or comparable measures should be undertaken periodically to determine program direction. Sequential evaluation is designed to be used in the intervening years, when policy and agroeconomic changes may affect the desired research direction, but when EA evaluation is too time-consuming or complex to carry out. It complements EA evaluation by continually updating prior assessments as new information becomes available, and as research, policy and market situations evolve. However, SE does not need to be based on a previous EA evaluation -- it is a self-contained procedure which can improve program management and implementation.

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[1] Sequential evaluation applies to either commodity programs or to specific projects. This paper focuses on applications to commodity programs of public agricultural research institutes.

2. ECONOMIC FOUNDATIONS

2.1 Dynamic optimization

The economic foundation of SE is a dynamic optimization problem which accounts for the intertemporal effects of research on social goals. The three social goals that are most important to research evaluation are economic efficiency, equity, and income stability (Norton and Pardey 1987). At the market level, these goals can be captured in the instantaneous criterion function:

$$(1) \qquad V(t) = V(dCS(t), dPS(t), dGE(t)).$$

In (1) dCS, dPS and dGE represent the changes in consumers' surplus, producers' surplus, and government expenditures, respectively -- caused by public research, technology transfer, and adoption. These changes are functions of time, which is denoted by t. The changes are measured from a base scenario in which no public research is undertaken. The function V is increasing in its first two arguments, since these surpluses measure the welfare of consumers and producers, respectively. V is decreasing in government expenditures since these funds must be raised from taxpayers.[2]

Industrial organization, market structure, institutional arrangements, and private research expenditures, among other factors, do not enter directly into the function. They are not social goals. They are factors which influence how public research programs relate to technical change, economic surplus and government expenditures. Hence these factors are captured in the measures of change in economic surplus and government expenditures. For example if an increase in public research activities merely replicates private R&D, then social surplus will not change as a result of the increased public sector activity.

When V takes the particular functional form of the sum of consumers' and producers' surplus less government expenditures, then its value is a measure of economic efficiency at time t. If, for reasons of equity, the government wants to favor producers (e.g. if producers are smallholders with low income), then it could weigh producers' surplus more highly than consumers' surplus and government expenditures. To capture the desire for economic stability, risk aversion can be built into (1). For example, the specific functional form

$$(2) \qquad V(t) = (w_1\, dCS(t) + w_2\, dPS(t) - w_3\, dGE(t))^{\alpha}$$

can capture efficiency, equity and stability considerations. If $w_1 = w_2 = w_3 = \alpha = 1$, then (2) simplifies to an economic efficiency criterion.[3] Equity considerations are incorporated when the weights w_1, w_2 and w_3 are not equal: In this case the group with the highest weight is favored. For values of α between 0 and 1, the criterion function places a premium on income stability.

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[2] A more general formulation of V includes public sector expenditures instead of government expenditures. At the national level these two are equal and the measure of expenditures need not include international donors grants. However, at the international level public expenditures should include donor grants.

[3] If there are welfare costs of generating government revenue, then efficiency would require $w_3 > 1$ to capture these costs.

The criterion function V is not limited to a single commodity or a single market: In any realistic scenario research will affect multiple markets. In this case it is easiest to think of the arguments of V as vectors of changes, with each element in a vector representing a particular market. Similarly, the weights in the specific functional form (2) can vary across markets. For example, producers of subsistence crops may be given higher weight than producers of cash crops, or consumers of staple foods may be given high weights.

The dynamic nature of research requires that intertemporal considerations be included in the model. A research program undertaken at time t = 0 will be optimal if it solves

$$(3) \qquad \max_{R(t)} \int_0^{\infty} e^{-\rho t} EV(t)\, dt$$

subject to budget and other constraints faced by the research director. In (3) ρ is a social discount factor, V(t) is the instantaneous criterion function described above, and E is the expectations operator. This operator is necessary because of the uncertainty inherent in forward looking evaluations. The choice variable, R(t), represents the time path of budget allocations to research (or some other measure of research undertaken). Since agencies undertake a multitude of research projects, $R(t) = (R_1(t),....R_n(t))$ can be thought as a vector, with each element representing the time path of expenditures on a particular project.

Properly including the relevant research, policy and agroeconomic considerations in (3), and then explicitly solving for the optimal time path of research expenditures, is at best a cumbersome process. Even if the optimal time paths are calculated at time 0, expectations about future events will never be exact. Consequently, these time paths would have to be revised at each instant as additional information becomes available. That is, at each future instant $t^* > 0$, the optimal time paths would have to be recalculated by solving a problem analogous to (3), but with an initial time of $t = t^*$ instead of t=0. This is impractical.

Sequential evaluation is a procedure which suggests how the time paths $R(t) = (R_1(t), ..., R_n(t))$ may be altered, without the burdensome requirements of continual dynamic optimization. As with any simplification it is inexact. Yet SE still captures the essential elements of the dynamic optimization problem defined by (I), (2) and (3).

The key to SE is to understand how the actual policy and agroeconomic situations diverge from those which were expected initially. If the initial decisions on research funding and direction were made appropriately, and if there is little divergence between the actual and expected situations, then the research program is probably on target. If divergences exist, then SE helps to understand how they affect research efficiency and how to adjust the research program in an efficiency-improving manner.

A conceptual example shows how SE redirects research programs in response to changing agroeconomic conditions. We begin with a simple description of how timing is related to the value of a program, based on Kitti (1985).

Let the net present value of the program be given by V.[4] Let T be the time at which the research outputs start to affect the market: we will call this the "lead time". T will be determined in part by the research strategy: purchases of high-technology equipment and hiring of additional scientists may speed innovation, and increases in technology transfer expenditures may speed farmer adoption. A smaller T means that the benefits will be realized more quickly, but decreasing T costs money. Consequently V will depend on T.

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[4] V can include non-economic objectives, as discussed earlier.

A net-value profile portrays the relationship between net value and lead time. Figure 2a depicts net-value profiles for two programs, a and b. For each program small values of T imply that research and extension are carried out quickly, increasing costs and leading to negative net values (V_a, $V_b < 0$). As the pace of research slows, costs decline, so that net value increases. However, slowing the research and extension pace also means that the benefits are not realized as quickly, and hence become less valuable. Thus V_a reaches a peak at T_a^*, and declines thereafter. The net value profile for program B follows a similar pattern, achieving a maximum net value with a lead time of T_b^*.

Suppose that an experiment station director has the opportunity to pursue both programs. He justifies these programs to his superior, and obtains funding to conduct both with lead times of T_a^* and T_b^*. Now suppose that an innovation in an agroclimatically similar country allows program b to borrow and transfer technology at a reduced cost. This shifts the net-value profile V_b to V_b', as represented in figure 2b. The availability of technology transfer increases the maximum net value, decreases the optimal lead time, and makes the profile more peaked (perhaps international competition increases as other countries adopt the new technique). It is now important that the priority given to program b increases be upgraded, so that it can be completed quickly.

Suppose that the station director asks for, but cannot obtain, another budget increase. In this situation it is optimal to reallocate funds away from a to b. By reallocating funds the lead time for program a will increase and that for program B will decrease. If the programs can be accomplished with lead times of T_a^{**}, and T_b^{**} then the portfolio value is $V_a(T_a^{**}) + V_b'(T_b^{**}) > V_b'(T_b^*) + V_a(T_a^*)$. Hence the reallocation increases the net present value of the portfolio.

This example draws out the need to update evaluations as conditions change. If a research organization misses the opportunity to borrow technology and fails to change program direction, then not only is the funding allocation suboptimal, but carrying out program B under the original allocation actually generates negative returns.

2.2 Factors affecting the social benefits and costs of research

The effects of policy and agroeconomic factors on the social benefits and costs of public agricultural research are summarized by four major considerations:

(1) Research opportunities for borrowing and developing technology, as responses to changing technological, market and non-market opportunities.

(2) The degree of coordination between input suppliers, farmers, research and extension, and marketing organizations, and its effect on the transfer and adoption of new techniques.

(3) Interactions with other sources of agricultural technology.

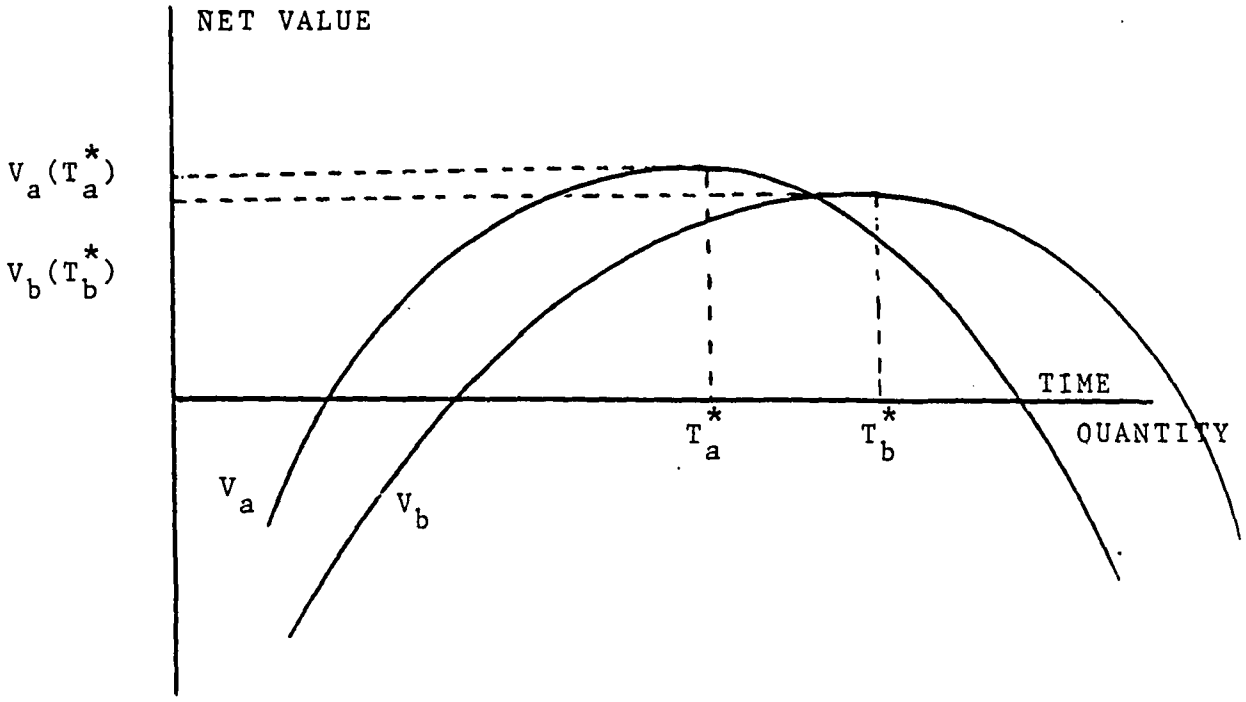
(4) Relationships between technical change and policy interventions.

These considerations are especially important when evaluating on-going research programs. This section shows how each of these considerations affects the social benefits and costs of research, and describes how changes in policy and agroeconomic variables affect each consideration.

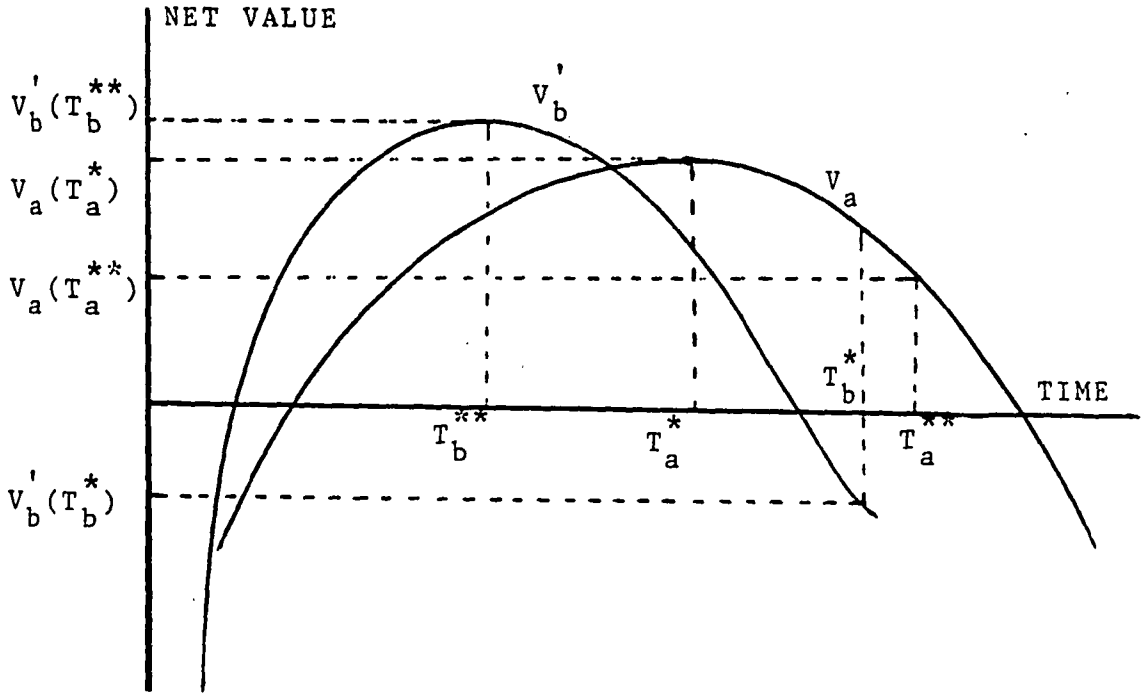
Research opportunity. Research opportunities arise from improvements in technological, market, and non-market prospects.

Figure 2. Use of net-value profiles in the selection of a research program

(2a) Initial research program selection



(2b) Selection after a change in agroeconomic conditions



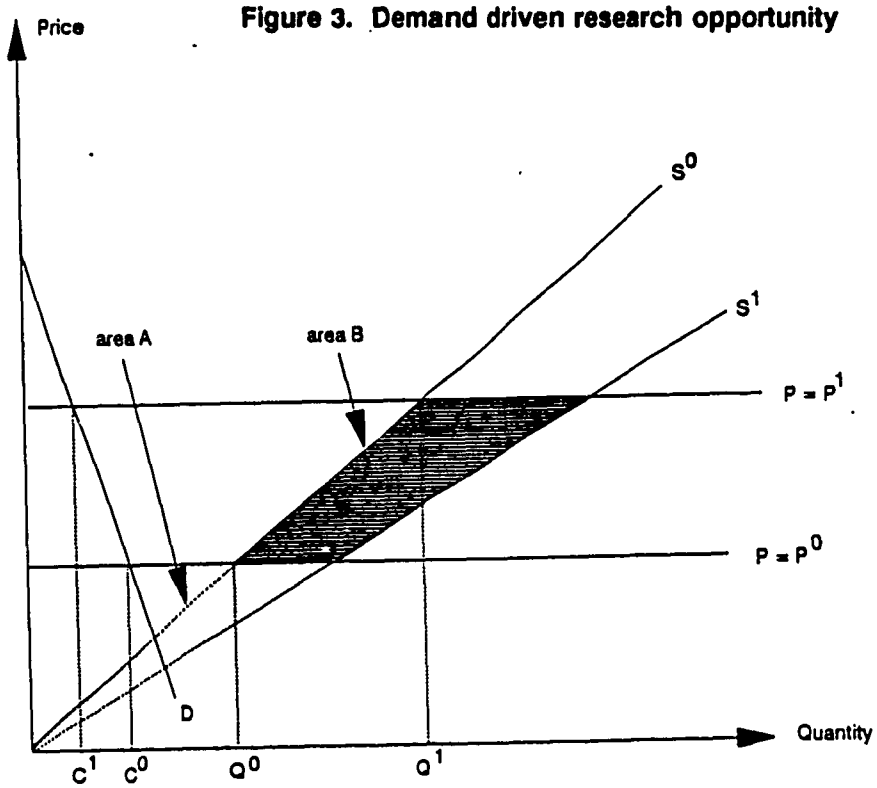
Technological opportunity originates when the odds of research success improve, or when a new, promising area of agricultural research arises. An example is a basic research breakthrough which unlocks high potential areas of applied research, or opportunities for technology borrowing from agroclimatically similar regions. For instance, the development of the Chilean table grape industry, which imported root stock from the U.S., is a consequence of appropriate technology borrowing.

Non-market opportunity originates with improvements in the odds of research success in non-traded commodities. An example of a non-traded commodity is one used entirely for home consumption. An example of research success is the development of an early maturing variety, which may have lower yields than late maturing varieties, but which provides sustenance during the pre-harvest, "hungry" season.

Market opportunity arises when improving economic circumstances increase the social profitability of successful research. Relevant economic circumstances include demand, macroeconomic, policy, income, and other factors. For example, if demand for a commodity increases, then it may become socially profitable to expand research in that commodity.

As an example of an improvement in a market opportunity, consider an increase in international demand. Figure 3 represents the domestic market for a small country producing an internationally traded commodity. Initially the domestic supply curve is given by S^0. The domestic demand curve is represented by D. Under the small country assumption, the international demand curve is represented by the horizontal line $P = P^0$, where P^0 is the world price.[5] The initial equilibrium price is P^0 and production is Q^0. Domestic consumption equals C^0 and exports equal Q^0-C^0.

Figure 3. Demand driven research opportunity



[5] By "small country" we mean that production and exports of a particular commodity from the country do not affect world price.

A successful commodity research program shifts the supply curve out from S^0 to S^1. Since prices are determined in the world market, this shift does not benefit consumers directly. Producers gain the area A in each marketing period after the shift. However, these benefits may not be large enough to justify the research program.

Now suppose that international demand increases unexpectedly. This increase is represented by a shift in the international demand curve, and the new curve is represented by the horizontal line $P=P^1$ at the new world price, P^1.

At the new equilibrium (in the absence of a supply shift) price increases from P^0 to P^1, domestic consumption falls from C^0 to C^1, production increases from Q^0 to Q^1, and exports increase from Q^0-C^0 to Q^1-C^1. The increase in production could be achieved by an increase in area planted, or in yields, or both. In most cases it is expected that area planted increases, as land is brought into production to take advantage of the higher price. For an internationally traded commodity, these changes in quantities produced, consumed and exported price, and area planted can be taken as indications of a shift in international demand.

As a result of the increase in international demand the benefits of research in any trading period are now augmented by area B. The total increase in social benefits is now the sum of the two areas, A+B. The larger benefit may justify a research program for this commodity.

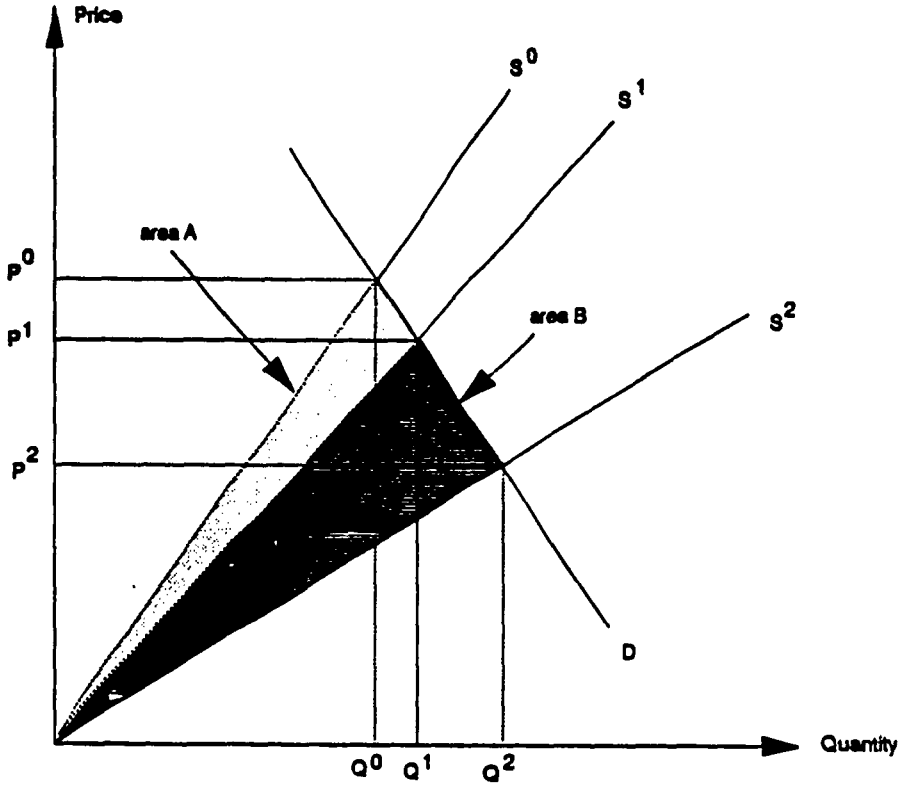
Transfer and adoption of new techniques. The transfer and adoption of new techniques is enhanced by coordination between input suppliers, research, extension, and output markets. The degree of coordination will affect the range of possible research programs that can be undertaken, and the success of chosen programs. For example, research systems linked to extension and input supply organizations may reduce farmers' uncertainty about new techniques and inputs. This increases adoption rates and speeds technical progress. If research develops a new variety that increases yields when grown with fertilizer and insecticide, then the presence of an organization which delivers these inputs in a timely fashion enhances the adoption of the new variety and the success of the research program.

Suppose a new innovation (which is profitable to farmers) is ready to be transferred to farmers in 1990. At this time the market supply and demand curves are given by S^0 and D in Figure 4, respectively. If the technology is transferred effectively, then the supply curve will shift rapidly. The curve S^2 represents the supply curve in 1995 after a rapid shift. S^2 lies well to the right of S^0, representing an effective transfer and a large supply response. The 1995 benefits from the innovation are the entire shaded area (A+B).

In the absence of effective transfer, only a few farmers will adopt the innovation in each year, leading to small shifts in the supply curve. The supply curve S^1 depicts this scenario. In this case the 1995 benefits from the innovation are equal to area A. These benefits are less than those obtained with an effective transfer. Without coordination between the research and technology transfer systems, the adoption rate may be so slow that it takes another ten years for the supply curve S^1 to shift out to S^2. Thus S^2 represents both the 1995 supply under an effective transfer, and the 2005 supply curve under an ineffective transfer. The ineffective transfer system means that society forgoes benefits equal to area B for these ten years.

When a profitable innovation is disseminated quickly by an effective system, price declines from P^0 to P^1 and production increases from Q^0 to Q^1. Typically this production increase will consist of both area and

Figure 4. Transfer and adoption of new techniques



yield increases. The lack of these increases may be indicative of poor technology transfer or of an unprofitable innovation.[6]

Interactions with other sources of technology. In addition to domestic research institutes, technical innovations are created by public research in other countries, international research centers, and domestic and foreign private sector research, domestic and foreign. Universities, cooperatives, foundations and input companies also conduct research and generate and transfer technology. As an example of other sources of technology we will focus on domestic private R&D.

Shifts in the supply curve due to technical change can be caused by public or private sector research. Real or potential complementarities between the two may diminish or augment the sum of the individual effects. The efficiency of local public research depends not only on its direct impact on supply, but on these interactions. Complementary research programs reduce duplication of effort and stimulate more applied private research, advancing social goals. An example of complementarity between public and private R&D could be the development of a crop variety where the public institute improves germplasm, which is in turn

[6] An innovation is unprofitable if the net benefits to farmers do not justify its adoption. Net benefits may be small because the innovation provides only small increases in yields, increases the sensitivity of yields to weather and other factors (and hence lacks yield stability) or requires costly additional inputs. Field trials could have detected these problems, although typically researchers do not cost out inputs used, and the controlled nature of field trials may mask yield instability. Once the innovation is determined to be profitable then low adoption rates may be indicative of ineffective transfer.

Figure 5a shows social returns to investments in public and private research, and their potential complementarities. It also accounts for spillover from R&D conducted in other countries. As new technology is adopted by farmers the supply curve S^0 shifts to S^3, increasing economic surplus. This shift captures the gains generated by public local research (area A), gains generated by private local R&D (area B), and the gains generated from transferring technology produced in other countries (area C). An example of technology transfer is importing chemicals for use with improved crop varieties. The total shaded area (A+B+C) represents social returns to public and private R&D and technology transfer when complementarities exist.[7]

If public and private R&D are substitutes (or independent) then the shaded areas A, B, and C are smaller, as depicted by the areas A', B', and C' in figure 5b. Substitutability implies that public R&D replaces private R&D, or that there is duplication of efforts.

If public and private R&D are complements, and an evaluation of public R&D is not cognizant of this fact, then the assessment of returns to public R&D will be incorrect. An evaluation based on the total shift in supply (S^0 to S^3) will overstate benefits by the area between S^1 and S^3 (area B+C). An evaluation focusing only on public sector research outputs will measure only the supply shift S^0 to $S^{1'}$, understating the benefits by an amount equal to area (A - A').

Private R&D and technology transfer should also be considered when calculating the costs of R&D. Total costs are the sum of public and private R&D expenditures plus the cost of transferring technology--which accounts for the monitoring of technology development in other countries and for maintaining a minimum research capacity to be able to benefit from foreign results.

Real and potential complementarities between public and private research (as well as with other sources of technology) are analyzed by including private R&D in the SE framework and by studying the determinants of private involvement in research. The understanding of the determinants of investment in research (such as market size, type of technology, and public sector policies) provides guidelines to address the public-private complementarity issue.

Policy interventions. Government policy interventions influence the effectiveness and efficiency of research programs. For example, a tax on an exported commodity, or an overvalued exchange rate, reduces the potential gains from research oriented towards that commodity. In general, policies which adversely affect the agricultural terms of trade also decrease the benefits from research and technology transfer. This makes the commodity less profitable at the domestic level by lowering output price. Farmers therefore will have a decrease in potential income per hectare.

Figure 6 shows the effects of an export tax in a country facing a downward-sloping demand curve for an agricultural commodity. The tax depresses the world price from P_w to the after-tax price, P_t. The consequent social deadweight cost to consumers equals area A; the deadweight cost to producers equals area B. The tax negatively affects the impact of past research in the commodity, and the potential benefits of future research. In the absence of the tax, social returns to R&D are depicted by the shaded areas C+D. Because the tax depresses price, only area C is actually realized by society. Under the tax area D is a dead weight loss.

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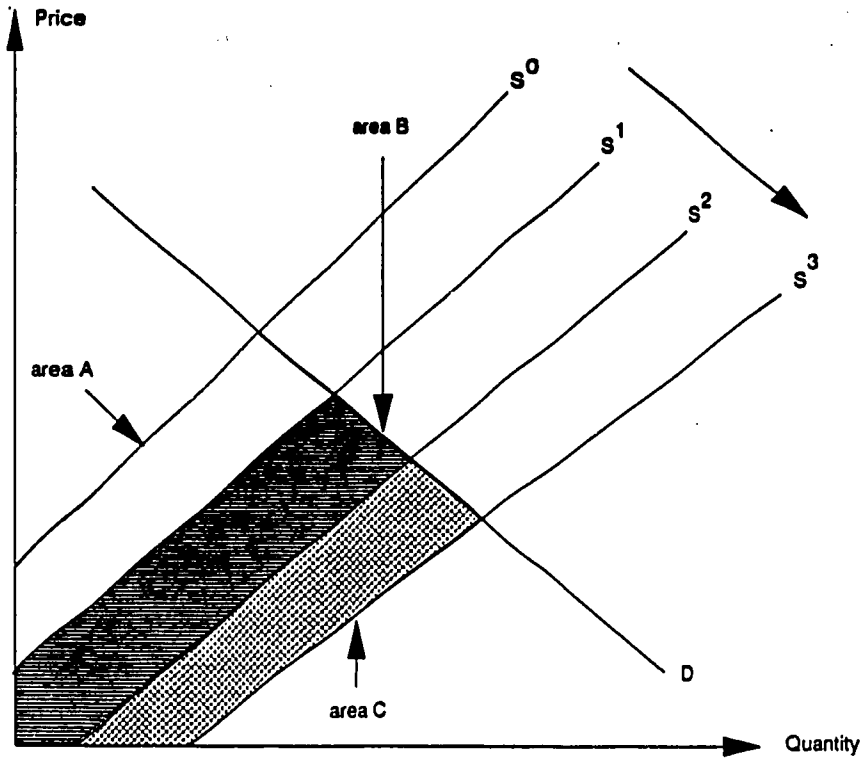
[7] This argument includes spillover and complementarity effects in Peterson's (1976) framework, who shows that social returns to private R&D must be greater than the private returns.

Figure 5. Social returns to public and private research

(5a) With complementarity



(5b) Without complementarity

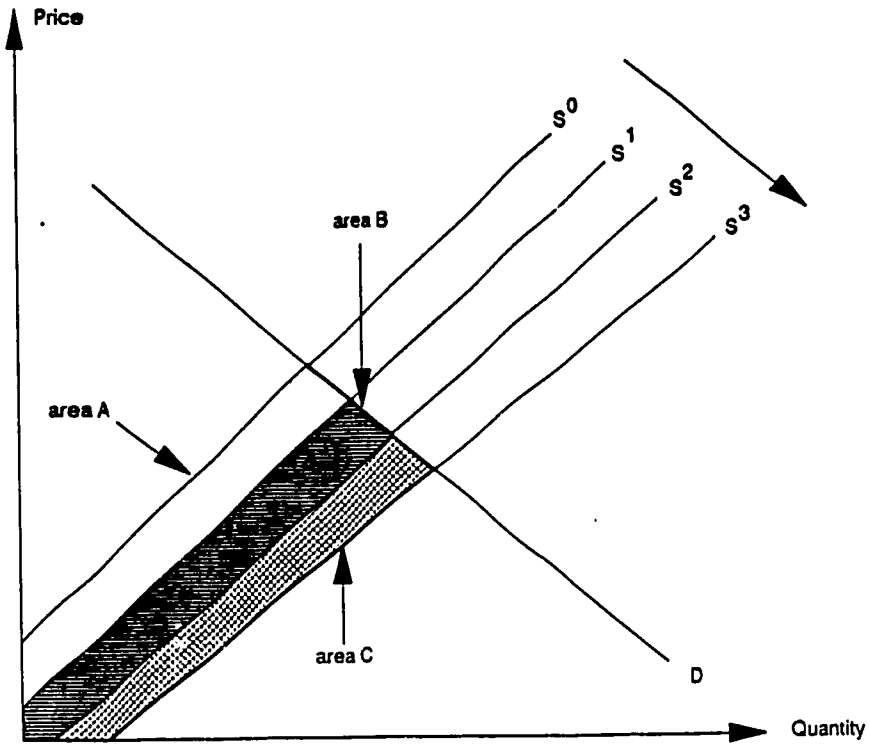
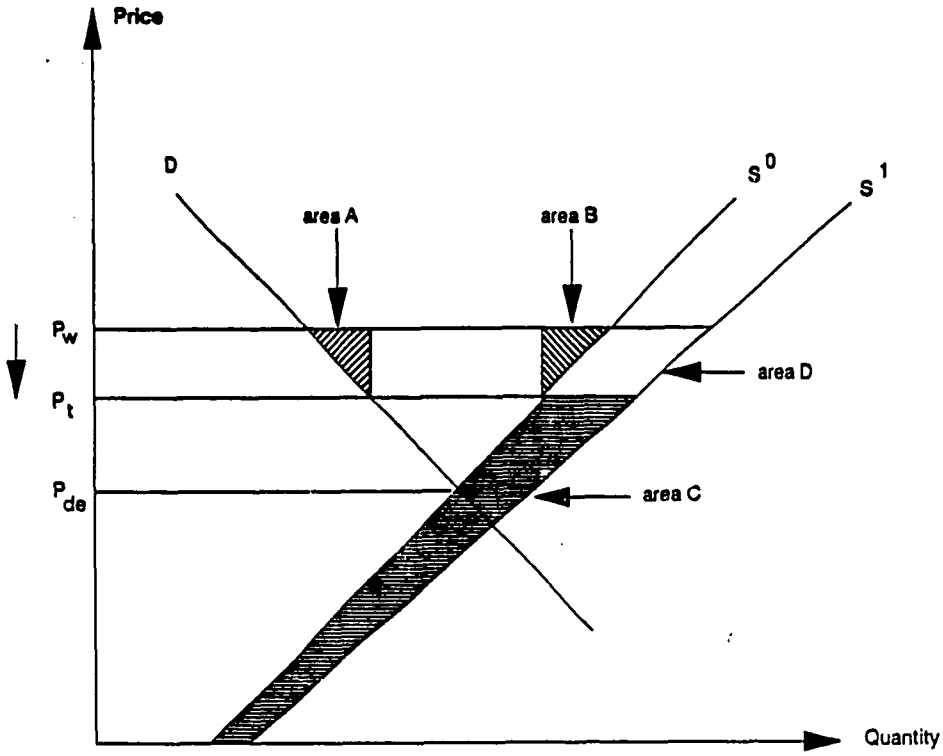


Figure 6. Distortionary policies and technical change, the effect of a tax on exports.



Directors of research institutes should account for these policy effects on the impact of technical change and modify programs accordingly and also inform policy makers of the consequences of their policy choices.

3. SEQUENTIAL EVALUATION INDICATORS

Sequential evaluation updates information to determine which factors influencing research have changed. It achieves this goal by utilizing a set of indicators arranged on five main factors:

1) research program characteristics, including human and financial resources;

2) other sources of technology, including private R&D and international research centers;

3) technology transfer and adoption by farmers;

4) agroeconomic environment, including general indicators and indicators of research opportunity; and

5) policy interventions.

Table 1 lists these factors and the associated indicators for a sequential evaluation of a research program. While these indicators are not exhaustive, they provide relevant information on the effectiveness of research, and can be updated on a regular basis, as new information becomes available. The remainder of this section examines these factors and indicators from a public sector perspective which would be taken by the administrator of a government research institute.

3.1 Research program

Four important **general characteristics** of a research program are: 1) the type of technology being produced (agronomic, biological, chemical, or mechanical); 2) the expected life of the innovation, i.e. how many years will the new technology be available before being replaced; 3) how many years the program has been operational; and 4) the type of priority setting mechanism(s) utilized to allocate resources among programs and within the program itself.

The research program **budget** includes all operational costs plus salaries and other expenses of scientists included in the program. It is also pertinent to examine the share of the total research budget allocated to salaries, operations and capital investments.

The potential (different) sources of funding for a research program also constitute relevant information. Public funds for research can originate from general tax revenues or from specific taxes on agricultural production or agricultural exports. Special research projects could also have their own internal or external source of funding, or they can be jointly funded by public and private organizations.

3.2 Other sources of technology

These sources are domestic and foreign public and private sector research. National research institutes, research divisions of ministries, and Universities are examples of possible domestic (public sector) sources of technology. International research centers are examples of possible foreign (public) source. There are many examples of private sector organizations that conduct research: input companies (local and multinational), processing companies, large farms and plantations, cooperatives, commodity groups, and foundations.

Table 1. Critical factors and indicators for a sequential evaluation of a research program

Critical Factor	Indicator
Research Program	
General characteristics	type of technology being produced
	expected life of the innovation (years)
	duration (years)
	type of priority setting mechanism
Human resources	number and level of staff, and trends
	ratio of scientists to technicians (%)
	different levels of staff training (number and %)
	turnover
Budget	costs ($/year)
	share of budget allocated to salaries, operations and capital investments
	sources of funding (% of funds coming from government, private sources, etc.)
Other sources of technology	
	source (domestic or foreign, public or private)
	type of research (basic, applied, etc.)
	type of technology (agronomic, biological, etc.)
	annual budget ($)
	staff (number, and educational level)
Transfer and adoption of technology	
	ratio of transfer agents to farmers
	average number of visits, meetings, and demonstrations per agent per year
	area under new technology (ha and % of total commodity area)
	number of farmers adopting (and % of total farmers producing the commodity)
	increase in benefits to farmers adopting ($/ha)

Agroeconomic environment, including research opportunity	
Economic structure of agricultural sector	share of ag. GDP on total GDP (%)
	share of value of exports on ag. GDP (%)
	production, area and yield of main commodities
	farm size (ha/household)
	land distribution among households (number of farms in given size ranges)
Economic importance of a commodity	production (tons, and % of ag. output)
	area (ha, and % of ag. area)
	value of output ($, and % of ag. GDP)
	exports (% of total production, and % of total value of exports)
Prices	domestic (regional and international price trends ($/year)
	relative output and input prices ($)
	seasonal price variation (% change)
	gap between domestic and international input and output prices ($)
Traditional and improved technology	yield (kg/ha)
	growing season (days)
	input use (quantity/ha)
	net income ($/ha)
Productivity gaps	yield gap between experiment station and farms, national and regional (kg/ha)
	yield trends (kg/ha/season)
Agroclimatic	soil use
	soil type
	climatic (temperature, rain, frost days, etc.
Non-market	environmental
	output quality
Policy interventions	
Priority to public agricultural research (and extension)	share of research (and extension) expenditures on total public ag. expenditures (%)
Priority to agriculture	share of total public ag. expenditures on government budget (%)

Fiscal capacity	share of gov. budget on total GDP (%)
Related policies	input and output subsidies and taxes
	price support
	land use restrictions
	government storage
	trade policies
	exchange rates

Four measures capture the extent to which different organizations are involved in research: 1) type of research activities, 2) type of technology, 3) budget, and 4) number and educational level of personnel. The first and second indicators show the proportion of the R&D budget spent on basic, applied, and adaptive research, and the type of technology being produced (mechanical, chemical, biological, and agronomic). These four indicators give public research administrators more information on the potential interactions with other public and private organizations.

3.3 Transfer and adoption of technology

A critical factor not often closely monitored by research programs is the transfer and adoption of technology. These two processes could be evaluated by having measures such as the ones listed in table 1 on the activities carried out by extension programs and on adoption of specific technologies. In order to explain the adoption results it is important to know the increased costs and benefits of adopting a particular technology.

3.4 Agroeconomic environment

The **economic structure** of the agricultural sector plays a crucial role in the potential impact of a research program.

The **economic importance of a commodity** can be measured by value of production, or proxied for by area planted or quantity produced. However, some crops are used primarily for home consumption, and so data on prices and production may be lacking. When available, household consumption surveys could indicate the nutritional contribution of various foods to the family diet.

A change in quantity produced is the result of shifts in supply or demand, or changes in policy. This indicator is the primary manifestation that the agroeconomic environment has changed, although it cannot differentiate among possible causes. Thus it is important to separate changes in quantity produced into changes in yield and in area planted.

An increase in the area planted to a commodity means that research which increases the profitability per unit area will realize an increased payoff. However, changes in the area planted can be caused by a number of factors, and it is important to examine which forces are at work. For example, a fertilizer shortage may cause a decrease in area planted to a high yielding variety, but this does not mean that research on improving that variety should be abandoned. An appropriate response might be to improve the fertilizer distribution network.

Other examples include the emergence of a disease in a crop. This may result in a large increase in the area planted to a substitute crop. In this case the research administrator could consider undertaking a program to eliminate the disease, or a program to improve profitability in the substitute crop. A third example is that the successful introduction of a high-yielding variety can increase area planted. In this case the change in area planted should be taken as a partial indication of research success, and not necessarily as an indication of the need to alter the balance of research programs.

Prices are a critical factor in the evaluation of a research program.

There are several measures of relative output price. The agricultural terms of trade (ATOT) is defined to be the ratio of agricultural to non-agricultural product prices (usually these prices are expressed as indexes). An increase (improvement) in the ATOT means that farmers can trade the same quantity of farm products for a greater quantity of non-farm products. This represents an increase in the relative value of agricultural products, and hence an increase in the value of successful agricultural research.

The commodity terms of trade (CTOT) of a particular commodity are measured by dividing its price by an average non-agricultural price. An increase in the CTOT reveals that the commodity has become relatively more valuable, increasing the value of successful research. A similar measure is constructed by taking the ratio of a commodity price index to an index of all agricultural prices. An increase in this ratio shows an increase in the importance of that particular commodity relative to all agricultural products.

An aggregate measure of relative input price is the ratio of agricultural input prices to agricultural output prices (usually measured as indexes). Increases in this ratio suggest that agricultural production technology is improving more quickly than input production technology. In this case the benefits of farming research may be captured by input suppliers and factor owners. An increase in the price of a particular input relative to all inputs may indicate a production problem: for example an increase in insecticide price may indicate a particularly severe pest problem and high demand for the insecticide.

Seasonal variations in output prices. Prices of staple crops can be collected on a monthly basis. A large increase in staple crop prices in the pre-harvest months followed by a large drop at harvest time indicates inadequate storage techniques or facilities, or low supplies of storable outputs.

The differences between **traditional and improved technology** can be analyzed by focusing on the input and the output side, and on specific agronomic characteristics. An increase in yield can reflect improvements in technology, or increases in the use of inputs per unit area. Stagnant (or decreasing) yields may indicate pest, disease, drought, ineffective technology transfer or other problems.

Two indicators of a change in input use should be considered: a change in quantity such as increased fertilizer use, and a change in quality such as a switch in seed types.

Information is an input into the adoption and efficient use of new technologies. Farm surveys can indicate the number of extension visits, publications and the availability of other information sources. These measures may also be available from organizational records such as extension service documents.

Productivity gaps are one factor influencing research opportunity.

Yield Gaps. The regional yield gap is the difference between yields in a country and in other countries growing the same commodity, with similar techniques, in approximately the same agroclimatic situation. A large yield gap is indicative of the possibility of technology transfer or adaptation. One difficulty with this measure is that it is hard for LDCs to maintain a dataset on yields and improvements in other countries (keeping abreast of the agronomic literature may serve the same purpose).

The domestic yield gap is the difference in yields between high productivity and low productivity areas. A large yield gap could be caused by differences in agroclimatic potential, or because research and technology transfer systems have previously ignored certain areas.

Yield stability. Fluctuations in yields of a particular crop across soil or agroclimatic regions or in response to annual rainfall variability within a region may indicate the need for condition-specific research. For example, suppose the length of the growing season is highly variable in a specific area, perhaps because of variability in the onset of the rainy season. This could indicate the desirability of developing an early maturing variety for use when the first rainfall comes late. Also, different yields across agroclimatic regions in a particular country might indicate the need for research to breed varieties for use in the low-yield regions, or for adaptive research on inputs (e.g. fertilizer, insecticide) that compensate for the natural resources lacking in the low-yield areas.

Relevant data on **agroclimatic conditions** improves the informational content of the other indicators. Relevant data include: rainfall, length of growing season, type of soil and potential soil use, and climatic cycles. Permanent or long-period climatic cycles may affect the emphasis of some research projects. For example, in many West African countries the cotton zone has been shifting due to persistently low rainfall. Appropriate research policy responses may be to examine drought resistance in cotton, or to adapt the current varieties to changing soil conditions as production areas shift.

The **non-market** indicators measure the effects of agroeconomic factors which are not always included in standard farm or market statistics.

Environmental Concerns. Sometimes research institutes are asked to increase agricultural productivity in environmentally sensitive areas. In these cases environmental quality should be monitored carefully. The relevant indicators will depend on the type of potential degradation, but considerations may include chemical runoff, excess animal waste, loss of forest, soil erosion, and others.

Output Quality. High quality products can open up new markets, and command higher prices in existing ones.[8] A research program which has the potential to develop a high quality output with low production costs should be viewed more favorably than a program which simply lowers productions costs of existing outputs.

Measures of quality are commodity and market specific. For example, the determinants of high quality cotton (length of fiber) are very different from the determinants of high quality beef (percent fat), and the definition of high quality may vary across markets.

For many commodities storability, nutritional content (as food or as livestock feed) and flavor are important determinants of the acceptability of crop and livestock products. Measurement of these characteristics, and the consequent classification of products as having "good" or "poor" quality characteristics, is a task for commodity specialists.

3.5 Policy interventions

When analyzing the policy environment in which agricultural research is conducted it is useful to distinguish between the priority a country (or a region) gives to agriculture and to agricultural research the fiscal

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[8] For example, the "Granny Smith" and "Fuji" apple varieties have made inroads into the U.S. market because of their superior tastes.

capacity from where resources could be committed to agriculture in general and to research in particular; and the role of agriculture in the economy.

In addition to these factors there are other related policies that affect directly or indirectly the impact of agricultural research, such as subsidies and exchange rate distortions. The better that research managers understand the effects of these policy interventions, the higher is the chance of establishing a more constructive dialogue with policy makers or to redirect research priorities.

When applicable, description of the existence of some of the policies listed in Table 1 and their perceived effects on research is sufficient. A thorough economic analysis is not necessary at this stage.

3.6 Implementation of sequential evaluation

An important issue that has not yet been discussed is how a public research organization implements SE. We argue that SE can be conducted by most research systems, and that it blends with other evaluations and monitoring procedures.

At what level (program, project, national, regional, local) **should the evaluation be implemented, and who does it?** SE could be implemented at the level of a socioeconomic unit within a research institute. A researcher with a background in economics and statistics could assemble data from available sources (or coordinate the collection of primary data), and calculate the indicators described above. This researcher should be able to identify patterns of change in the indicator series, when change is present, and interpret these patterns in the context of the research system.

Where do the data come from? Data can be collected from various sources. Information on the research program should be available from the program administrators or scientists.

Much of the required price data will be available from Ministries of Finance, Commerce or Trade, or from economic analysis units within the Ministry of Agriculture. Production, area planted and yield data may be available from the Ministry of Agriculture. At the national level these data might be available from international organizations such as the United Nations. If the SE is conducted at the regional level, then these data should be collected at that level.

International yield gap data will be difficult to obtain if little information is available on yields in agroclimatically similar countries. The international yield gap proxies for the probability of research success and the scientific potential of the output. Often researchers can provide comparable (or better) information.

Input data can be obtained from farm surveys or from input suppliers. For improved inputs such as high-yielding seed varieties, input suppliers often have detailed records of quantity distributed by variety and geographic location.

The amount of information transferred to farmers could be approximated by quantities of radio transmissions, magazine articles and advertisements, field visits, or other transfer mechanisms. These statistics may be available from the relevant organizations. In the absence of organizational records, a farm survey may be required.

Data on the amount of R&D conducted by other organizations (for example, in the private sector) is hard to obtain. Companies do not release information about their R&D activities. However, many will participate in confidential surveys if the results are for use only by the research system. Commodity organizations (such as a seed growers association) are another source of information.

Commodity or marketing specialists may be the most appropriate source of information on quality of marketed outputs, while farmers are aware of the quality of products consumed on the farm.

Scientists may be able to provide some estimates of environmental degradation, or at least come up with some relevant metrics. Experiment stations can provide rainfall, length of growing season, and other agroclimatic data.

How should the results be used? The simplest use of SE is for the researcher to relate patterns of agroeconomic change to modifications in the evaluation of certain types of research. These modifications are then conveyed to decision makers. For example, suppose that the administrator decides not to fund a research program with high expected returns, but which wouldn't generate benefits under some foreseeable scenarios. An SE could indicate when the agroeconomic environment has progressed to the point at which these negative scenarios are unlikely to occur. The administrator can then redirect research funding to the high return program.

For research systems that have undergone EA program evaluation efforts, SE is an updating tool. Most EA evaluations do not rely on any single benefit-cost prediction, but make predictions corresponding to the most likely set of future research and agroeconomic scenarios (sensitivity analysis). By updating information on the agroeconomic environment, SE indicates which of these scenarios is closest to reality, thereby directing program adjustments.[9]

The use of SE should be strengthened by additional information. Knowledge of probabilities of future events is not always embodied in current indicators.[10] Dramatic changes in any single indicator, or persistent changes in a large number of the indicators, suggests that more complete information is necessary.

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[9] If the EA procedure does not provide a sensitivity analysis, the predicted benefits and costs are still predicated on a particular expectation about future events. SE indicators are examined closely to find out if the actual situation is an improvement or deterioration of the expected situation, and the appropriate adjustments are made.

[10] For example, suppose that predictions of the world price of long-grain rice assume that the real price is stable. With the expected unification in 1992 of the EC -- an important long grain rice importer -- previous expectations about world price may change.

4. AN EXAMPLE OF SEQUENTIAL EVALUATION: RICE RESEARCH IN URUGUAY

This section discusses how SE could be applied to the Uruguayan rice research program. In 1985 an EA exercise ranked rice with a high research priority (Norton and Ferreira 1987). An EP study estimated a high payoff to investments in rice research and technology transfer from 1960 to 1985 (Echeverria et al. 1989). Changes in the international rice market since 1985 justify an SE.

The example presented in this section is not comprehensive: an SE of the Uruguayan rice research program was not conducted. A complete SE would require additional information, and might lead to different implications for the research system. The purpose of this example is to illustrate how such an SE might proceed. The example also illustrates the relationship between the implications for the redirection of the research program and the four issues described in section 2.2.

4.1 Changes in the international rice market

We begin the example with background material (USDA 1989; FAO 1988) on exporters and importers of rice and the international market. World rice exports increased during the 1960s and 1970s to more than 12 million tons per year by the early 1980s. Starting in the late 1970s Asian production of long-grain rice increased, causing a decline in their imports. Higher incomes in the Middle East induced these countries to triple imports between 1970 and 1981. In the latter part of the 1980s Africa become an important consumer in response to income growth in oil producing countries, and increases in food aid and credit. However, the total volume of world trade did not grow significantly in the 1980s.

Uruguay produces high-quality, long-grain rice. It exports both milled and parboiled rice. Uruguay rice production has increased during the 1980s from less than three hundred thousand tons to over four hundred thousand tons, most of which is exported.[11]

Thailand has become the world's leading rice exporter. In 1989 Thailand exported almost five million tons, or over one-third of the world trade; some of these exports are parboiled, long-grain rice for sale to markets in African and the Middle East. Thailand's emergence as a major exporter is due to its 1986 removal of export taxes on rice. Guaranteed prices of US$ 194-233 per ton on are used to encourage exports of basmati rice to the Middle East, Canada and the U.S.; due to its lower price basmati sometimes competes effectively with higher quality long-grain rices. The Thai Rice Mills Association expects rice area to fall over the next 5-10 years as industrialization draws labor out of the farm sector. However, they are urging an increased emphasis "on larger plantation areas and applied technology and machinery, such as tractors and harvesters, to lower production costs" (USDA 1989:12). Even if area planted in Thailand declines, lower production costs could put downward pressure on the world price.

The EC, Africa and the Middle East will remain the biggest importers of parboiled and other long-grain rice. Both the US and Thailand expect to compete in these markets. Approximately one-third of US production is exported, and the proportion of US exports which are parboiled is increasing, targeted mainly at Africa and the Middle East. US consumption of rice is increasing due to "increases in the Asian and Hispanic segments of the population, a shift in American diets towards more grain-based foods, and introduction of new products, such as flavored package mixes, cereals, and snack foods..." (USDA 1989:19).

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[11] See Echeverria et al. (1989) for a description of rice production and export trends, composition of the industry, and the significance of research and technology transfer activities in the evolution of this industry.

Uruguay may export a large proportion of its rice output to Brazil in the near future: "Brazil is expected to import 150,000 tons in 1989, mostly from Uruguay. In 1990, imports could rise to 250,000 tons..." (USDA 1989:9). The current drought in Turkey may increase their imports in 1990, and Uruguay could compete well in this market.

Current GATT negotiations are attempting to liberalize agricultural trade. Removal of import restrictions and levies, would increase imports by Japan and the EC. Reduction of export and production subsidies by the US and Thailand will lower world production. Increased imports and decreased supplies would put upward pressure on the world price.

Once relevant information has been collected, SE determines which indicators have changed significantly over time. For Uruguayan exporters the most important indicator is the world price, which has fluctuated widely over the last few years (Table 2). World price peaked at US$ 500 per ton in August 1984, then slid to a low of US$ 224 per ton in Spring 1987, and then increased to nearly US$ 500 per ton for parts of 1987/88. The amount of rice traded in world markets is small compared with total production, less than 15 million tons in a total of 486 million tons for 1989. This implies that a small percentage change in quantity produced can lead to large percentage changes in world trade, and consequent fluctuations in world price. The different upward and downward pressures on world price discussed above suggest that price volatility may continue for the next few years.

Additional changes affecting rice production in Uruguay include the rise in the world price of beef and the expected decrease in the area planted to rice in Uruguay, in response to the decrease in the export price of rice. Beef is the most important agricultural commodity produced in Uruguay. In the rice growing area, beef cattle are fattened in pastures sown in rotation with rice: recommended practice is to establish a pasture (a combination of productive grasses and high-quality legumes) after two years of rice. After approximately four years of pasture the land is returned to rice. A rise in the price of beef relative to rice could induce farmers to include more years of pasture in the rotation, effectively reducing area planted to rice.

4.2 Implications for the research program

The next step is to link the underlying agroeconomic changes to possible changes in the research program. These changes are analyzed in the context of the four major considerations described in section 2.2.

Research opportunity. Declining world rice prices suggest that opportunities for production research to improve social welfare are limited. At this time Uruguay might want to restrict new, long-term research programs. However, increases in agricultural productivity which lower production costs will help to offset the negative effects of price declines, so that socially profitable research on rice production could continue.

Opportunities for adaptive research on borrowed technology will continue. Borrowing of Texas long-grain varieties in the 1960s promoted the Uruguayan rice export industry. These opportunities are discussed more fully in the subsection on other sources of technology.

The research program could also continue attempts at diversifying the techniques used by farmers. For example, most farmers plant one variety. Current attempts to expand genetic diversity should be continued to insure against possible pests and disease. Diversity can also be achieved by changes in the rotation timing, or in the type and productivity of non-rice crops (for example soybeans). The availability of profitable alternative crops insures agricultural income against a fall in the world market price of rice.

Table 2. Changes in the international market

Indicator			1984	1985	1986	1987	1988	1989
US rice production								
total (million ton)			6.3	6.1	6.0	5.9	7.2	7.0
share of long-grain (%)			69	74	73	69	74	na
Thai rice production								
total (million ton)			19.9	20.3	18.9	18.0	21.0	21.5
share of exports (%)			na	na	23	24	23	28
World rice trade								
total (million ton)			12.6	11.5	12.6	13.0	11.0	14.6
World price (US$/ton)	1982	1983	1984	1985	1986	1987	1988	1989
rice[a]	530	488	527	495	418	260	408	312
rice[b]	418	428	435	410	323	290	na	na
beef[c]	1199	1162	1208	1127	1328	1555	na	na

na = not available

[a] U.S. No. 2 milled average C&F composite quotations at Rotterdam (USDA 1989).

[b] milled long-grain No. 2 fob Texas (FAO 1988).

[c] all beef export average fob Argentina (FAO 1988).

Changes in US population and dietary habits suggest an opportunity for profitable post-harvest research to increase the value of exported products. For example, rice cakes and other rice products are natural entrants in to the emerging US market for low cholesterol, low fat snacks. Since the Middle-East market is relatively new, there may also be opportunities to develop products specifically for this region.

Post-harvest research could be supplemented with market research oriented towards determining what types of rice products consumers want, and how to make potential consumers (including domestic consumers) aware of newly developed products. The development of a strong processing industry will depend on coordination between farmers' cooperatives, processors, and wholesalers. In the absence of coordination processing firms will have no market, and wholesalers will have no product.

Transfer and adoption of technology. A number of newly developed rice varieties yield over 5 tons per ha in Uruguayan experiment station plots, although they may be more suceptible to pests than currently grown varieties. In addition to developing a technical package which enables farmers to increase yields, the research program could assist in the transfer of these techniques to the farmers, and encourage adoption of the entire package. The package could include a high-yielding variety, a change in growing conditions unfavorable to pests and the use of chemicals which also retard pest activity. The transfer and adoption of this package depends on coordination between the research system and the input suppliers who deliver the seed and chemicals (either private companies or a cooperative). Processors and shippers will also need to be involved, to insure that consumers do not react adversely to the use of chemicals, and so that the larger harvest can be shipped (or stored) quickly and efficiently.

Other sources of technology. For rice, there is a well organized public-private R&D interaction in Uruguay. This probably could be strengthened by an increase in both public and domestic private sector funds allocated to rice research, and by a better integration with foreign sources of technology, such as international research centers and national research systems.

In the past many improvements in Uruguayan rice production have been the result of effective technology borrowing. The cost of borrowing from other countries and international centers has been low relative to benefits received. Continuing rice research and technological advance in other parts of the world suggests an opportunity for profitable borrowing. Because developments in biotechnology may lead to rapid changes in agricultural technology, borrowing will become increasingly important.[12] To encourage borrowing, contacts with other research systems with similar agroecological conditions (such as in Texas) and with IARCs (such as CIAT and IRRI) needs to be expanded. Technology borrowing requires domestic research capacity, so that the current rice research program could emphasize expanding contacts with scientists from other countries. Continued research and technology borrowing can maintain Uruguay's advantage as a low-cost producer of high quality rice.

Policy interventions. The Uruguayan rice market and the markets for inputs into rice production face relatively little domestic intervention. Rice production and research has responded well to economic incentives. This constitutes an example of an export-oriented strategy that could be expanded to other commodities.

The Uruguayan rice sector suffers from adverse, foreign-country trade policies. The US and Thailand are the major competitors in the long-grain markets, and both countries subsidize production and exports. Japan and the EC are potentially large importers of long-grain rice. However, import quotas and levies restrict access to these markets. A research program can do little to counteract these policies. Hopefully

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[12] For example, nitrogen fixing algae could improve nutrient intake and lower fertilizer costs under current Uruguayan growing conditions.

restrict access to these markets. A research program can do little to counteract these policies. Hopefully future GATT negotiations will help to open these markets. If this is the case, then Uruguay should be prepared with an aggressive research program to increase production and an effective merchandising program to market the additional output. Uruguayan exports a small fraction of world trade, which facilitates finding markets for competitively priced rice.

5. CONCLUSIONS AND FUTURE WORK

Sequential evaluation is a procedure for the assessment of ongoing agricultural research programs. It complements ex-post and ex-ante methodologies and incorporates dynamics, research opportunities, other sources of technology, transfer and adoption of technology, and policy interventions.

The sequential evaluation procedure developed in this paper provides a set of indicators which measure change in the research and agroeconomic environments, and assess the impact of these changes on the social benefits and costs of research. These indicators reflect research program characteristics in addition to four major components of the agroeconomic environment: research opportunity, other sources of technology, technology transfer and adoption, and policy intervention. The economic analysis in this paper has shown the importance of each of these components as factors which determine the net social benefits from research.

An example shows how sequential evaluation might be applied to the Uruguayan rice resarch program. Recent changes in world market conditions suggest that the program be reassessed. Despite some adverse market developments, a partial analysis indicates that there is a continuing need for rice production research, technology borrowing, and marketing research.

Future work will be operationalizing this sequential evaluation procedure by carrying out a case study. This will allow a field test of the procedure and indicators described in this paper.

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